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Flipped Science Fair Invites Children to Judge Graduate Student Posters Through a University-Community Partnership

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ABSTRACT: Flipped Science Fairs put power directly into children's hands, inviting them to judge graduate student science fair posters. At the fair, graduate students practice communicating their research to a young audience, while children have the opportunity to see themselves as valued contributors in science. Here, we present a model for a walk-in Flipped Science Fair, designed in partnership between nine Virginia Tech graduate students and the Roanoke City Public Libraries (RPL; Roanoke, VA, USA). At our event, 27 graduate students presented posters about their research, with an audience of over 250 community members. We found that hosting the Flipped Science Fair at a public library lowered barriers to entry for participants and allowed us to reach an audience further from the university. While judging posters, children learned about a wide range of leading-edge research and had meaningful interactions with diverse scientists in small-group settings. Conversely, for graduate students, this event and associated training workshops provided an opportunity to practice communicating their research to a new audience. Throughout this article, we share our experience as graduate students collaboratively conceptualizing and organizing this community-oriented Flipped Science Fair with public library partners.

INTRODUCTION

Early childhood experiences with science, technology, engineering, and math (STEM) have been identified as a crucial factor shaping students' interest in STEM fields (National Research Council, 2009; Dou et al., 2019). These experiences contribute to the development of perceived occupational self-efficacy, which in turn influences the range of career options that children consider (Bandura et al., 2001). As persistent racial and gender gaps remain in many STEM fields (e.g., Cimpian et al., 2020), childhood experiences with STEM may be particularly influential for minoritized students, and interactions with diverse role models may increase the likelihood that students see STEM fields as viable career options (e.g., Cheryan et al., 2015). Developing and implementing a broad suite of outreach events with diverse role models may be imperative to foster interest and self-efficacy in STEM for all students.

STEM outreach events not only benefit the children they target, but also the participating mentors and organizers. For graduate students, assisting in STEM outreach can provide valuable training in science communication, which is not traditionally taught in STEM higher education programs (Brownell et al., 2013). While many scientists consider public communication (e.g., when requested by a journalist) to be an important professional duty (Peters, 2013), public-facing communication often requires different delivery and framing than the technical communication that is taught and practiced in graduate training programs (Lupia, 2013; Scheufele, 2013). These obstacles may be addressed through

careful thought and attention to practicing science communication with diverse audiences (von Winterfeldt, 2013). In particular, previous outreach events have been shown to strengthen graduate student science communication skills through the discussion and practice of communication with broad audiences (Clark et al., 2016; Chamely-Wiik et al., 2019; Kompella et al., 2020; Ufnar and Shepherd, 2021).

Graduate students who engage in or organize outreach events may find that these activities also advance their future career goals by helping them develop leadership skills. For example, a survey of job advertisements and interviews with professionals in the field of conservation determined that multiple conservation career pathways value collaborative project management and program leadership, especially when demonstrated through extracurriculars outside of direct graduate work (Blickley et al., 2013). However, while organizing outreach events can be beneficial to graduate student career goals, few models exist for sustainable graduate student-led outreach programs that accommodate the substantial time constraints associated with graduate training programs.

The Flipped Science Fair. An innovative approach that addresses both the need for science outreach to children and the need for graduate student training in science communication is the Flipped Science Fair. In a typical Flipped Science Fair, presenters (often graduate students or postdoctoral researchers) create short presentations about their research, then receive feedback from young (often 10- to 15-year-old) judges. Flipped Science Fairs have been hosted at several universities (Mervis 2010; Mernoff et al., 2017; Benedetti and Crouse, 2020), with consistently positive outcomes. Notably, putting children in a position of power as judges can encourage participation, as children feel a responsibility to pay close attention and provide a thoughtful evaluation (Mervis, 2010). Furthermore, previous research in educational contexts has suggested that using positional cues to de-emphasize an instructor's authority can promote STEM identification for marginalized students (Hazari et al., 2014); this role reversal in Flipped Science Fairs may similarly help encourage children to see themselves as valued contributors in STEM.

Flipped Science Fairs have been conducted in widely varying formats across institutions as organizers have modified each event to fit contextual needs. For example, Yale organizers integrated their Flipped Science Fair with the Yale Pathways to Science program, which provides STEM outreach to a select group of middle and high school students who show particular promise in STEM (Benedetti and Crouse, 2020). At Tufts University, the Reverse Science Fair connected classes of high school students with graduate student researchers. Graduate student participants later served as judges for the more traditional high school science fair (Mernoff et al., 2017). Notably, Flipped Science Fairs have become particularly popular in neuroscience outreach efforts, thanks in part to the pioneering work of Deborah Colbern, who first developed a Flipped Neuroscience Fair in 1992 to help her neuroscience graduate students communicate their research to a broad audience (Mervis, 2010). While these events have all reported substantial successes, to our knowledge all previous Flipped Science Fairs have been organized at least in part by professional educators or outreach staff, limiting the applicability of these examples to less-formalized student groups that are also often engaged in STEM outreach (e.g., Schwab et al., 2018).

As with many university outreach programs, Flipped Science Fairs to date have tended to focus on the communities immediately surrounding universities (Mervis, 2010; Mernoff et al., 2017; Benedetti and Crouse, 2020). This geographical proximity is useful for several reasons: notably, it limits the transportation needs for university-affiliated presenters and participants and helps build connections between the university and the surrounding community. However, the emphasis on hyper-local outreach can create inequities in access to high quality STEM outreach experiences, with the areas immediately surrounding a university receiving disproportionate education and outreach opportunities.

Here, we present a model for a walk-in Flipped Science Fair, designed in partnership between nine Virginia Tech graduate students and the Roanoke City Public Libraries (RPL). Through this collaboration, we reached out to children in the city of Roanoke, VA, USA, 40 miles driving distance from the Virginia Tech campus in Blacksburg. In Roanoke, 15 out of 17 elementary schools receive support from Title I, which is allocated to schools in which at least 40% of students are from low-income families. RPL has established strong connections with the surrounding community, which facilitated broad participation in this outreach event. Throughout this article, we share our experience as graduate students collaboratively conceptualizing and organizing a community-oriented Flipped Fair and associated training workshops with public library partners.

PROGRAM DESCRIPTION

Our Flip the Fair program included two training events for graduate student poster presenters, in addition to the one-day Flipped Science Fair event, where children judged graduate student science fair posters (Figure 1). Through this program, we worked with 27 graduate student presenters, all of whom received training and practice communicating their research to diverse audiences prior to the event. Over 250 community members, including 45 child judges, attended the walk-in Flip the Fair event.

We organized this program over seven months and in close collaboration with library partners. To facilitate rep-

Figure 1. Graduate students created tri-fold posters and presented their work to child judges. Photos by Carla López Lloreda.

lication of the event, especially by graduate student teams, below we describe in detail our planning process, the recruitment and training of graduate presenters, logistics for the day of the Flip the Fair event, and the documentation and promotion of the event's success.

Planning Process.

Timeline. Initial conceptualization for this program began in August 2021, seven months before the Flip the Fair event would take place (Figure 2). Over the following months, our organizational team applied for and received a "Sharing Science" grant from the American Geophysical Union (AGU), which provided a substantial portion of the funding for the program. We began talking with RPL very early in the idea development process (September 2021) and began presenter recruitment and training approximately four months before the day of the event, which was held on February 5, 2022 (Figure 2).

Organization. Running this event required a substantial time commitment on behalf of organizers and presenters, but the load was made lighter by dividing tasks among the nine graduate student organizers. Throughout the planning process, our full group of organizers met approximately once per month, with more frequent meetings as we approached the day of the Flip the Fair event. To lower the time commitment for each individual organizer, we employed a decentralized approach and separated into three sub-committees early in the planning process: the Funding Committee, whose responsibilities included applying for the AGU grant, managing the budget for the project, and soliciting prize donations; the Day-Of Committee, who coordinated the library partnership and Flip the Fair logistics; and the Workshop Committee, who planned graduate student workshops. In total, we estimate that each of the nine members of our organizing team contributed an average of 30 hours of planning time over the course of seven months.

For four of the organizers on our team, this project was done as a capstone project for the Interfaces of Global Change

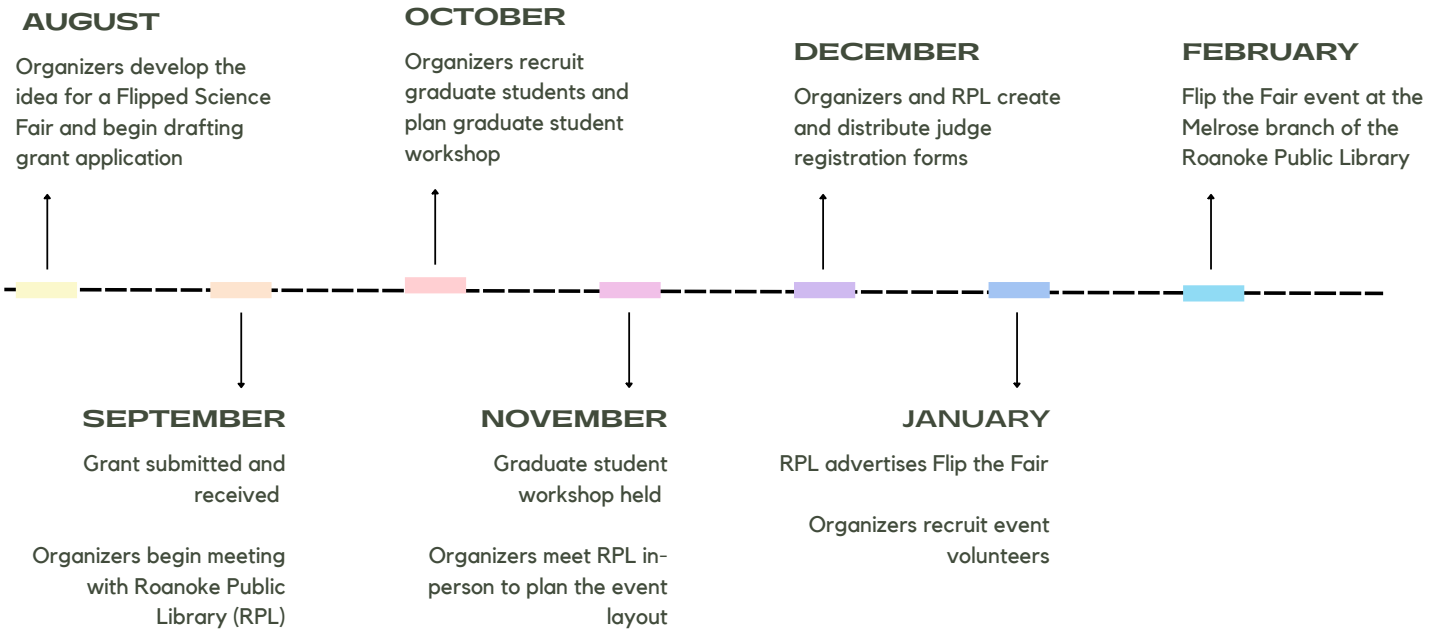

Figure 2. Timeline for the development of our Flipped Science Fair program.

graduate fellowship program at Virginia Tech, which made it easier to prioritize dedicating time to this work. Other graduate students may also be able to find a way to get academic credit for organizing similar outreach programs, for example by including a chapter on outreach in their thesis or designing a project as part of a course requirement or independent study.

Library Collaboration. It was important to the organizational team to work with a community collaborator that had the facilities to host our event and could make it accessible to families that would be unable to travel to the Virginia Tech campus in Blacksburg, VA. While multiple venues were discussed during initial planning meetings, one member had an existing relationship with RPL and was able to secure their support and partnership. The Youth Services team at RPL showed particular interest in collaborating on a Flipped Science Fair and was able to contribute discretionary funds, staffing, and a venue for the event.

The Day-Of Committee met regularly with RPL staff to discuss a variety of topics including event logistics (e.g., date and time of the Flipped Science Fair, how many RPL staff would be needed for the event), task delegation (e.g., who was responsible for sourcing equipment), set up (e.g., event layout), and promotion (e.g., communication with schools, development of advertisements). Meetings were held every two weeks, which was essential for maintaining open lines of communication and sharing information among collaborators. Three months before the event, one meeting was held in-person, allowing the Day-Of Committee to tour the library branch and plan the event set-up with RPL (Figure 2).

RPL played a critical role in the success of this event. RPL librarians identified the Melrose Branch Library, which is their branch oriented towards Science, Technology, Engineering, Art, and Math (STEAM), as a suitable venue for our event: it has considerable open space, ample parking for visitors, and a STEM lab. The Day-Of Committee and RPL staff worked together to create an event layout that maintained an appropriate amount of space between presenters within the Melrose Branch Library to meet ongoing COVID-19 safety requirements. RPL Youth Services librarians recruited elementary school judges using an established STEM program in Roanoke City Public Schools and word-of-mouth promotion to library patrons and their families. They also created a map of the library to aid in coordination during the event, and purchased materials including trophies for the graduate student winners of the science fair and giveaway items for the child judges (Table 1).

To reflect the library venue for this event, we asked all graduate students to choose a favorite children's book that is either STEM-related or directly relevant to their research. Librarians then created a slideshow of the graduate presenters and their chosen books. The slideshow was displayed on televisions throughout the event to encourage child judges to continue learning about the presenters' research (Figure 3).

Table 1. *Items purchased or borrowed for the Flip the Fair program, approximate value, and whether these items were essential to the success of the event. Footnotes indicate funding source for each item. We note that the event also had other related expenses (e.g., library personnel, food truck, video production) that were not handled by organizers and are not represented in this table.*

Item	Approximate Value (USD)	Essential?
Poster materials (e.g., trifolds, paper, glue, scissors)	150*	Yes
Materials for the day of the event (e.g., clipboards, pens, sharpies, nametags, maps, stamps)	150*,‡	Yes. Some materials can be borrowed
Awards and trophies for graduate presenters	250*,‡,§	Strongly recommended. Cost can be brought down by soliciting donations
Goodie bags for child judges	300*,‡	Strongly recommended. Cost can be brought down by soliciting donations
Thank you cards for partners, workshop leads, sponsors, etc.	25*	No
Snacks for graduate student workshop and Flip the Fair event	100*	No
Speaker fee for graduate student workshop	100*	No
Door prizes (raffle)	300*,§	No
Materials requested by graduate presenters to enhance their displays (e.g., covid-19 plush)	100*	No
Transportation costs (here, gift cards to graduate student drivers)	60*	No
T-shirts and stickers for presenters	1000†	No

* *"Sharing Science" grant from the American Geophysical Union*
† *Center for Communicating Science donation*
‡ *Roanoke Public Library contribution*
§ *Donation (other)*

Other Community Partnerships. Several other community partners also contributed to the Flip the Fair event, and many of these partners were recruited using library resources and contacts. For example, the staff at RPL invited the Kiwanis Club of Roanoke, which is a major benefactor for the branch, to set up a station at the Flip the Fair event for

Figure 3. Each presenter picked a favorite children's book that related to their research, and these recommendations were featured during the event. Here, a television screen displays Whitney Woelmer and her chosen book, *The Gardener* by Sarah Stewart.

children to learn about gardening. At this station, each child was given a pot with soil and flower seeds to take care of at home and later plant in a new garden outside of the library. Additionally, RPL arranged for a food truck from Feeding America Southwest Virginia to be present at the event, providing free meals to participants and library patrons. A member of our organizing team contacted the Carilion Clinic's Simulation Center, which also set up a station at the event, bringing tools and equipment to the library for the children to learn about how medical students practice surgical skills. These additional activities added to the Flip the Fair event by providing hands-on activities and food to keep children engaged before and after judging posters.

Budget. Our Flip the Fair program was funded primarily through a "Sharing Science" grant from the American Geophysical Union, a donation from the Center for Communicating Science (CCS) at Virginia Tech, and many contributions from RPL. We also received support from numerous community organizations in the form of donated prize items for graduate students and child judges.

Financial support helped make this event particularly fun and exciting for presenters and judges, but very few of the items in our budget are essential to running a Flipped Science Fair event (Table 1). For those with limited funding availability, we suggest that purchasing poster materials is a top priority, in order to avoid imposing a financial burden on graduate presenters. Most other expenses can be avoided by borrowing materials and soliciting prize donations from community organizations.

Graduate Student Recruitment and Training. We recruited a total of 27 graduate student presenters from across 13 departments at Virginia Tech, with most presenters coming from the biomedical and environmental or ecological sciences (Figure 4). Presenters spanned many stages of graduate school (i.e., 1st–5th year) and included a mix of both masters and doctoral students. To recruit presenters, our organizing team used program-specific listservs and word of mouth conversations with other students in the university.
To help graduate students be mindful about how they communicate their research at the Flip the Fair event, we hosted a mandatory training event for graduate student presenters before the event, along with an optional educational seminar that was open to the broader Virginia Tech community.

Mandatory Training. The mandatory graduate student training included exercises in science communication and diversity, equity, inclusion, and justice (DEIJ), as well as an introduction to the goals and logistics of the event (presentation slides in Appendix A). At the end of the workshop, we distributed poster-making supplies (tri-fold posters, construction paper, glue sticks, scissors, etc.) to all participants. This workshop was run simultaneously with participants on two Virginia Tech campuses and on Zoom; members of our organizational team were on-site in both locations to facilitate the event.

The science communication component of the graduate student training event was run by Virginia Tech's Center for Communicating Science. This communication workshop (Figure 5) drew from principles of improvisational theater, teaching graduate students to make their science communication more direct, personal, spontaneous, and responsive. As an example, one of the exercises required graduate students to distill their research into a 30-second pitch, which forced them to think about the most important takeaway of their research. Graduate students also practiced removing jargon and complex terms from their pitches, and discussed the many reasons why they do their research, including why

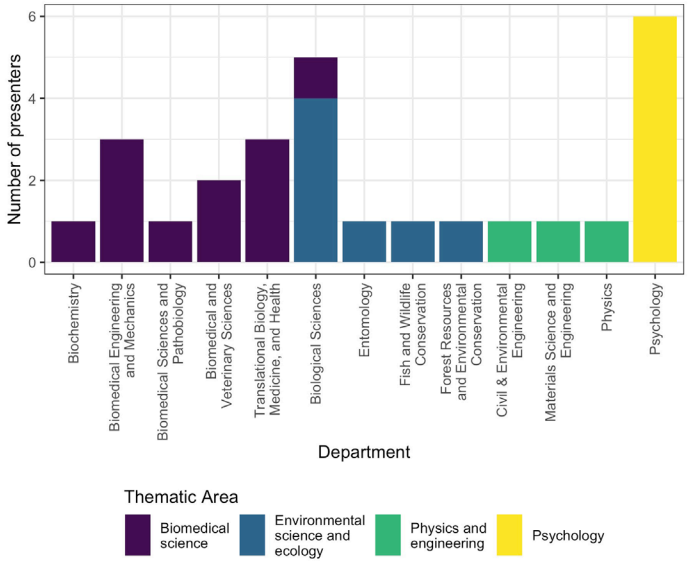

Figure 4. Graduate student presenters came from 13 different departments across Virginia Tech, with most presenters coming from the biomedical and environmental/ecological sciences.

Figure 5. Patricia Raun, director of Virginia Tech's Center for Communicating Science, leads graduate students in a science communication workshop based upon principles of improvisational theater.

Figure 6. All participants were greeted at a check-in table, where they received goodie bags, raffle tickets, clipboards with judging forms, and name tags.

their work matters to themselves, their research community, and the broader public. A follow up email sent to all presenters summarized the take-home messages of the workshop, and could be adapted for future Flipped Science Fairs (Appendix B).

To help support the integration of DEIJ considerations into graduate students' presentations, the mandatory graduate student training also included a DEIJ-focused workshop. This workshop was led by Dr. Justin Grimes, Leadership and Inclusion Associate for the Fralin Biomedical Research Institute at Virginia Tech, and the goal of the workshop was to examine potential biases graduate students may have when interacting with a diverse audience. Dr. Grimes used powerful examples and metaphors to help provide participants with tools for speaking with intent.

Culturally Relevant Science Communication. An additional event, led by the scientist and science-communication expert Dr. Mónica Feliú Mójer, was held on a separate day and was implemented virtually. The focus of Dr. Feliú Mójer's workshop was to consider different cultural backgrounds and integrate culturally relevant approaches in education efforts. Dr. Feliú Mójer shared her personal experiences of working in Puerto Rico during the COVID-19 pandemic and highlighted the importance of tailoring communication to cultural context in order to most effectively communicate scientific research.

Flip the Fair Event: Set Up and Organization.

Event Summary. During our Flip the Fair event, 27 graduate students presented their handmade science fair posters and were evaluated by child judges (approximately ages 8–10; Figure 1). The event drew a large crowd, with over 250 community members attending over the course of two hours. Following the poster session, graduate students were recognized for their work and creativity at an awards ceremony, where they received prizes based on evaluations from the child judges.

Set-Up Logistics. Setting up the Flip the Fair event took several hours of work from organizers and RPL. To make the day more manageable, much of this work was done before the event. Organizers (Day-of committee) and RPL met at the library on the day before the fair to set up tables and signage and put together goodie bags for child judges. By doing this work in advance, organizers were better prepared to handle last-minute logistics and questions from presenters on the day of the fair. An hour before the beginning of the fair, presenters arrived, put on their T-shirts and name tags, and found their assigned table numbers. During this time, organizers also set up a break room filled with snacks and drinks to allow presenters a space to step away for a few minutes if needed during the event. Just before the fair began, we gathered all of the presenters for a quick meeting and warm-up exercise to get them ready to interact with the children, allowing for any final questions to be answered before the event started.

Judging Process. As judges entered the library, they were greeted at a check-in table, where they received a goodie bag, a clipboard with judging forms, and a name tag (Figure 6). We explained that it was their mission to evaluate the presentations to the best of their ability and that after completing and returning the judging form they could enter a raffle for prizes from local (Blacksburg, VA and Roanoke, VA) businesses. Each child was assigned to judge four presentations, and we allocated these assignments considering both the total number of evaluations each poster would receive (i.e., number of judging forms) and the total number of times each poster would be visited (i.e., the number of judging groups). Children were welcome to visit and judge more presentations if they wished after finishing their assigned four. Small groups of judges (ca. 1–4) were then paired with volunteers (n = 14) who guided them around the library to their assigned posters. Volunteers played an important role in this event not only by helping child judges navigate the event, but also by talking with the judges and families about the graduate research and transcribing comments for the younger judges.

The judging form for this event was designed to be simple

Judge's Name: _____

Use this form to rate each of the posters you visit. *Make sure to record the presenter's name at the top of each judging section!*

After looking at the poster and talking to the presenter, *write in a score between 1 and 5* for each question. 1 is the *lowest* ranking (the presenter did not do well in that category) and 5 is the *highest* (the presenter did very well in that category). Fractions are ok!

Poster Number: _____ Poster Presenter Name: _____

Questions:	Score:
How well did the presenter explain why their research question was important?	
How clear and well-designed were the presenter's methods (how they did the experiment)?	
How well did the presenter explain what they discovered and why it matters?	
How did the poster look? Was it easy to understand the main points by looking at the poster?	
Other feedback (for example, what did you like? What could be improved? What did you learn? What questions do you have after looking at the poster and talking with the presenter?)	

Figure 7. Judging form used by child judges to evaluate graduate student presentations.

and accessible for child judges, while providing useful feedback and evaluation for presenters (Figure 7). It was loosely based upon the type of evaluation that is done at traditional science fairs, helping children gain familiarity with these expectations before participating in traditional science fairs as presenters themselves. Specifically, judges were asked to numerically evaluate presenters in each of four categories: research question, methods, results, and poster design (Figure 7). After the event, judges' comments and evaluations were sent to all presenters for feedback on their poster presentations and science communication.

Awards. Awards were given to the graduate student presenters after the event, with first through third place awards in each of four different categories—Curious Questioner, Master of Methods, Radical Results, and Prettiest Poster (Figure 8). In addition, a Top Presenter award was given to the presenter with the highest total score. First place winners were awarded larger gifts, while second and third place winners were allowed to choose from a variety of smaller prizes.

COVID-19 Considerations. Unfortunately, there was a surge in COVID-19 cases in our area during December 2021–January 2022, which forced us to limit the number of children that were invited to the event. We did this by asking families to register for the event on a first-come-first-serve basis, though walk-ins were also welcome on the day of the event. We asked half of the registered attendees to come at 1:00 pm and the other half to come at 2:00 pm to try and maximize the ability for social distancing. We also asked that everyone wear a mask and provided masks for those who needed it. Our goal was to make sure everyone in attendance felt as comfortable and safe as possible so that they could enjoy the event.

Event Documentation and Promotion. To document the Flipped Science Fair, we partnered with the Center for Communicating Science at Virginia Tech, who led the creation of two short documentaries about the event. The first video (10 minutes) described the event as a whole, featuring interviews with organizers and child judges, while the second (7 minutes) focused on the graduate presenters (links to the videos can be found in Appendix D). Both videos were created by Caleb Robbins, an undergraduate student hired by the Center for Communicating Science for this documentary project. These documentary videos served as a long-term resource for organizers, the Center for Communicating Science, and RPL to promote the success of this event and encourage replication, and they helped lend a sense of achievement and a record of accomplishment to the project for all the graduate student participants and organizers. Furthermore, the video interviews provided a fun opportunity for the graduate student presenters and organizers to reflect on their involvement and the impact it had on their communication skills and engagement with a younger audience.

In addition to these videos, we have documented the Flipped Science Fair through local news and academic

Figure 8. Five trophies were awarded to top-ranked presenters: Curious Questioner, Master of Methods, Radical Results, Prettiest Poster, and Top Presenter. These trophies were purchased and provided by the Roanoke Public Libraries (RPL).

conferences. Our event was covered in a Roanoke newspaper the day of the event and was the most-read story on the newspaper's website that day. In academic contexts, we have presented this work both locally (within Virginia Tech) and internationally at the Joint Aquatic Sciences Meeting in Grand Rapids, Michigan, May 2022. Through these presentations we aim to inspire and provide resources for others to host similar events in the future.

PRELIMINARY PROGRAM ASSESSMENT

Assessment Method. We used a variety of methods to solicit feedback from our graduate student presenters and volunteers, as well as from the elementary student participants and their parents. One form of informal feedback came from the judges' forms themselves: each form had space for general comments from children during the event (Figure 7), and these often-enthusiastic responses gave an initial impression of the child judge's response to the event. Additionally, the library assisted in sending out online post-event surveys to parents for more formalized feedback (Appendix C). For graduate student presenters and volunteers, we distributed a survey to solicit feedback on the events leading up to and during the event (Appendix C). While our program did not entail a rigorous evaluation of learning goals, these basic program assessments provide useful information about what went well and what could be improved in future events.

Our protocol was approved by Virginia Tech's Human Research Protection program, with a determination that this preliminary program evaluation was not human subjects research. To protect participant privacy, particularly because this project involved children, we did not collect any sensitive or personally identifiable information in survey responses. We saved excerpts from the child judges' written comments, though we did not retain the names of any judges.

Assessment Results and Discussion.

Small-Group Interactions Fostered Excitement for STEM. The feedback we received from children, parents, and graduate students was consistently positive, though responses were limited (12 of 27 presenters, 1 of 14 volunteers, and a total of 8 parents; the total number of parents in attendance was unknown). Child judges (n = 45) were often effusive about their excitement for graduate student presentations. One judge encapsulated this excitement in their feedback for a graduate presenter, writing "it was very cool and it was very awesome and it was very cool and awesome!" Comments like this highlighted that our event had succeeded in fostering excitement for STEM. Children's excitement was also reflected in parental survey responses. One parent of a child judge stated in our post-survey, "As a parent, I very much valued my kids learning about new things and seeing how cool research can be," and another reflected, "Students made a huge effort to create posters that engaged the kids. Just amazing!" Quantitatively, when parents were asked to "rate how much your children enjoyed the event on a scale of 1 to 5 (5 is awesome)," the mean score was 4.9, and all parents answered yes when asked if they would like to attend another event like this in the future. Importantly, these preliminary assessments demonstrate that for many of the child judges the Flip the Fair event was an exciting and new way to engage with STEM.

As child judges assessed the graduate student posters, they had the opportunity to interact directly with scientists in small group settings; responses from both children and presenters highlight the power of these small-group interactions for STEM education. One judge was particularly glad to interact with a graduate student studying a topic close to home, writing on the evaluation form, "My cousin had cancer and it helped me understand better." Through this one-on-one interaction, this child was able to learn more about cancer directly from a researcher in the field. Seeing children grasp the research concepts was in turn rewarding for graduate presenters. For example, one graduate student wrote, "Watching a student judge have that 'I get it' moment when explaining something on my poster was very impactful and is one of the reasons I'd like to do it again." Another graduate student highlighted that "The most impactful part was when I saw kids telling each other about my research in the hallways." From these responses it is evident that judges meaningfully engaged with the scientific research that presenters shared, and this exchange was one of the highlights of the event for both child judges and graduate students.

For graduate students, this event provided a unique opportunity to practice making their science communication more direct, personal, spontaneous, and responsive, the Center for Communicating Science goals introduced in the training workshop. Graduate student survey responses often highlighted the value of this science communication training. For example, one respondent highlighted how Flip the Fair uniquely pushed graduate students to consider and adapt to multiple audiences when communicating their research: "I really felt like I was able to interact with the student judges and since it was a poster presentation I was able to pivot the level at which I presented [so the presentation was] personally catered to a 5 year old vs. a 7 year old vs. a curious adult." Another respondent reflected that this opportunity for science communication helped reinvigorate their own research, stating, "Learning and practicing how to distill my research to the most important message was very useful. The student comments I received reminded me of the importance of my field and why I decided to go into it." All graduate student respondents indicated that they would be interested in participating in this event again in the future as a presenter, volunteer, or organizer.

Event Volunteers Helped the Walk-In Event Run Smoothly. Hosting our Flipped Science Fair as a walk-in event meant that the event needed to be flexible to changing crowd volume and a broad range of participant ages; event volunteers played an important role in allowing for this flexibility. While the event was originally designed to target children ages 8–10, we welcomed anyone who was interested in participating. Often, this meant that siblings of the children that had registered were equally involved in judging posters, with ages ranging from around four to 15 years old. Volunteers played a critical role in helping tailor the experience to this broad range of ages. As one presenter noted, "Having guides for the students was a great addition and allowed younger students to participate more." Furthermore, volunteers also aided in education and confidence-building. One volunteer specifically spoke to this in their survey response, stating, "I felt I was able to engage with the student judges and make them feel confident in asking questions and learning." Of the eight parent survey respondents, seven reported that they thought having an escort was helpful.

Graduate Presenters Expressed Interest in a Larger Event. Due to COVID-19, we did not widely advertise this event, and we were only able to accommodate approximately 250 participants over the two-hour event. In their feedback about the event, presenters often mentioned hoping that this event can be scaled up in the future. While having more judges would have been cramped in this indoor space (as reflected in survey comments), presenters suggested hosting the event in a larger venue or hosting it several times and in multiple locations may help to accommodate more participants. Once posters have been developed, graduate students are able to easily repurpose their materials in the future.

When scaling up the event, it will likely be necessary to re-examine the number of volunteers needed to help the event run smoothly. Here, we found that our 14 volunteers and several members of our organizing team were in high demand for leading children to posters throughout the event. Alternative event formats could consider having children proceed along a dedicated route without a volunteer to guide them or use teachers or parents as chaperones.

Training Workshops Build Skills and Community, But Timing is Key. Graduate students reported appreciating the training in science communication and DEIJ that were offered in association with this event. The main constructive feedback that we received from graduate students was to hold the training workshops closer to the Flip the Fair. Several students commented that they didn't have plans for their poster yet when we hosted the workshop, and it would have been more beneficial to have an event dedicated to poster-making 2–3 weeks before the Fair. Still, these workshops provided an important opportunity for graduate students to interact and start developing ideas for the fair. Unexpectedly, many presenters also highlighted that these in-person workshops were particularly valuable because they allowed students to interact across departments. As one graduate student commented, "It was also really fun to interact with other scientists from other departments! I feel like I'm always with my same little bubble from my cohort, and the pandemic hindered a lot of in-person mingling." For many graduate students, the opportunity to interact with other presenters and start forming a sense of community before the Flip the Fair event seemed to be a helpful component of this overall outreach program.

Flipped Science Fairs as an Adaptable Outreach Program. Flipped Science Fairs have been hosted in multiple locations and widely varying event formats. The benefits to child judges and graduate presenters that we documented from this event are further supported by previous Flipped Science Fair assessments (Mervis, 2010; Mernoff et al,. 2017; Benedetti and Crouse, 2020).

Synthesizing results from our program and previous Flipped Science Fairs, one of the most striking findings has been the level of enthusiasm from child (or young adult) judges. For example, 96% of the child judges surveyed by Benedetti and Crouse (2020; n = 117 responses) either agreed or strongly agreed that they enjoyed the Flipped Science Fair. In our event, one graduate student presenter noted enthusiasm from child judges when they commented that "The most impactful part was when I saw kids telling each other about my research in the hallways." Similarly, Mernoff et al. (2017) noted several instances where the high school student judges told peers about posters they should make sure to see, displaying excitement about the research. One of the goals of our Flipped Science Fair was to promote perceived occupational self-efficacy by encouraging children to see themselves as valued contributors in STEM (Bandura et al., 2001). While perceived occupational self-efficacy has not been specifically assessed in Flipped Science Fairs to date, high school students involved in the Flipped Science Fair program described by Mernoff et al. (2017) tended to report increased interest in future laboratory research and increased excitement for engineering and science as possible career options after the Flipped Science Fair. Mernoff et al. (2017) also noted that student judges particularly benefited from the opportunity to interact with diverse, young, and relatable scientists. Future assessments are needed to better quantify whether similar impacts are seen for younger judges. Regardless, these responses clearly indicate that Flipped Science Fairs have the potential to be an exciting, new way for children and young adults to engage with scientific research.

For graduate presenters, our results and the results of previous Flipped Science Fairs collectively underscore the

benefits that this format of outreach event can have for training researchers to communicate with diverse audiences, a critical skill that is not traditionally taught as part of graduate education programs (Brownell et al., 2013; Peters, 2013). Surveys conducted before and after the Flipped Science Fair program described by Benedetti and Crouse (2020) indicated substantial gains in graduate student confidence presenting data and communicating the importance of their research to lay audiences. Flipped Science Fairs may be particularly beneficial as a means of developing science communication skills because they involve multiple presentations over the course of a day, allowing graduate students to practice and iteratively improve their framing based on the judges' comments/questions and non-verbal responses (Mernoff et al., 2017). In our program, at least one presenter noted the value of this format, which pushed them to pivot their presentation to "a 5-year-old vs. a 7-year-old vs. a curious adult." By communicating their research to diverse audiences, graduate students become better prepared to engage with the public throughout future careers within or outside of academia.

Importantly, our event required several key modifications from previous Flipped Science Fairs. While previous Flipped Science Fairs have tended to focus on the communities immediately surrounding universities (Mervis, 2010; Mernoff et al., 2017; Benedetti and Crouse, 2020), hyper-local outreach can create inequities in access to high quality STEM outreach experiences, with the areas immediately surrounding a university receiving disproportionate attention. By partnering with RPL, we were able to target a community further from the university's campus in Blacksburg, VA. Hosting the event as a walk-in Flipped Science Fair at the library required flexibility to changing participant numbers over the course of the event, and this flexibility was facilitated in large part by the volunteers that escorted groups of child judges through the fair. Overall, we found that our adaptation created an accessible Flipped Science Fair with very low barriers to participation for child judges.

CONCLUSIONS AND LESSONS LEARNED

Through our Flip the Fair event, we aimed to simultaneously provide STEM outreach to children in Roanoke, VA and train graduate students in science communication. Overall, this first event was a resounding success! Throughout the organization process, our team learned important lessons about successfully designing science outreach events and collaborating both within and outside of the university setting. To increase the replicability of this event and inspire future programs, we share five key lessons learned from co-organizing this program:

- **Lesson 1: Take the leap**. Organizing a program on this scale was ambitious, particularly for graduate students, who often need to prioritize degree requirements over outreach efforts. However, pushing to make this happen was empowering and rewarding. We enthusiastically encourage others to pursue the development of similar events!
- **Lesson 2: Maintain a group of enthusiastic, trusted collaborators.** Flip the Fair was successful in part because it harnessed the skills, energy, and connections of a large group of enthusiastic co-organizers. Taking a decentralized approach to project management was necessary for our team because no one co-organizer had sufficient time to oversee every aspect of project development. We found that by dividing up tasks and responsibility broadly across the group and trusting others to follow through, all collaborators maintained a strong sense of ownership and engagement in the project.
- **Lesson 3: Community partners are critical**. This event would not have been possible without substantial support from the RPL, and was made many times better by the contributions of other partners, including the Center for Communicating Science at Virginia Tech. We found that hosting an outreach event further from a university center entailed some additional logistical considerations (e.g., transportation), but building connections with RPL helped us reach a more diverse audience outside of the university's typical outreach sphere. We are excited that the library is eager to partner on this again in the future!
- **Lesson 4: Funding is a challenge and an opportunity.** We applied for funding for this program very early in the ideation process, and we found that developing a grant proposal was key to crystallizing our plan for the program. Working on this proposal forced us to think critically about our outreach objectives, program evaluation, budget, timeline, and relevant community partners.
- **Lesson 5: Share and celebrate.** Following the fair itself, one of the most rewarding aspects of this project has been sharing our experience and encouraging others to take and adapt what we have done. Communicating the success of the event has helped keep organizers and partners excited, potentially increasing the sustainability and continuity of the event.

Final Thoughts and Future Directions. Through our Flip the Fair event, we put power directly in the hands of elementary school students, inviting them to judge graduate student science fair posters. Ultimately, the success of this event reinforces how valuing children's voices may enhance both

outreach and educational goals. We hope that this Flipped Science Fair model can serve as inspiration for future programs and that the feedback we received can be adapted to continue improving such events.

ASSOCIATED CONTENT

Supplemental material mentioned in this manuscript can be found uploaded to the same webpage as this manuscript.

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Author Contributions

All co-authors contributed to organizing the Flip the Fair outreach event, as well as writing text for this manuscript. Data collection and analysis was led by AH, ASL, GOM, and GKP. ASL and GKP developed figures and tables for this manuscript, with input from all co-authors. ASL and GOM led the initial conceptualization of this manuscript, and ASL led the synthesis of text from all coauthors. All authors edited and approved the final manuscript.

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ABBREVIATIONS

AGU: American Geophysical Union; CCS: Center for Communicating Science; DEIJ: Diversity, Equity, Inclusion, and Justice; GCC: Global Change Center; ICTAS: Institute for Critical Technology and Applied Science; IGC: Interfaces of Global Change; NSF: National Science Foundation; RPL: Roanoke City Public Libraries; STEAM: Science, Technology, Engineering, Art, and Math

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